



Veterinary Antimicrobial Use and Food-Safety Implications Among Food-Producing Animals in Sokoto, Nigeria: A Three-Year Retrospective Study

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ABSTRACT

Background: Antimicrobial use (AMU) in food-producing animals is a recognised driver of antimicrobial resistance (AMR) selection under the One Health framework, and when medicines are used close to slaughter or without withdrawal-period compliance, it's a direct contributor to antimicrobial residues in foods of animal origin. Residues and resistant foodborne pathogens both represent tangible consumer-protection hazards distinct from, though related to, the resistance-selection concern that dominates most veterinary AMU literature. This study assessed patterns and temporal trends of AMU among food-producing animals at a multi-species veterinary clinic in Sokoto, Nigeria, between 2021 and 2023, with particular attention to the food-safety implications of the observed prescribing pattern. **Methods:** A retrospective analysis was conducted using timestamped clinical records for avian, bovine, caprine, and ovine cases documented between January 2021 and December 2023. AMU was defined as documentation of at least one antimicrobial agent in a clinical case record. Antimicrobial agents were standardised by generic name, grouped into pharmacological classes, and further mapped, exploratorily, to the WHO Access, Watch, Reserve (AWaRe) framework. Differences in AMU and antimicrobial class distribution across years and species were evaluated using Pearson's chi-square tests of independence, with Cramér's V as effect size; all statistics were computed specifically on the four-species food-producing subset. **Results:** A total of 14,252 food-producing animal clinical cases were recorded, comprising 7,014 ovine (49.2%), 4,736 caprine (33.2%), 2,214 avian (15.5%), and 288 bovine (2.0%) cases. Antimicrobials were documented in 12,169 cases (85.4%), rising from 84.2% in 2021 to 87.0% in 2022 and 86.2% in 2023 ($\chi^2 = 15.32$, $df = 2$, $p < 0.001$; Cramér's $V = 0.033$). AMU varied significantly by species ($\chi^2 = 298.05$, $df = 3$, $p < 0.001$; Cramér's $V = 0.145$). Oxytetracycline was the most frequently documented antimicrobial (5,387 of 14,367 entries; 37.5%), a compound independently confirmed to exceed regulatory maximum residue limits (MRLs) in Nigerian beef, poultry, and fish in multiple prior residue-testing studies. Tetracyclines constituted the largest antimicrobial class (41.2%), and antimicrobial class distribution differed significantly by year ($\chi^2 = 542.53$, $df = 20$, $p < 0.001$) and species ($\chi^2 = 1894.72$, $df = 30$, $p < 0.001$; Cramér's $V = 0.210$). Exploratory AWARe classification indicated 84.1% Access-category and 15.9% Watch-category entries, with Watch use highest in avian cases (22.3%), a species in which enrofloxacin and tylosin, both documented above MRLs in independent Nigerian poultry-residue analyses, were disproportionately represented. **Conclusion:** The prescribing pattern documented at this clinic, dominated by tetracyclines and administered without recorded withdrawal-period guidance or residue testing, aligns closely with the antimicrobial classes independently confirmed to exceed maximum residue limits in Nigerian meat, milk, and poultry products in the published residue-surveillance literature. This convergence between prescribing volume and documented residue risk supports treating veterinary antimicrobial stewardship and food-safety residue surveillance as a single, linked priority for food-producing animal practice in Sokoto State, rather than as separate concerns.

Keywords: veterinary antimicrobial use; food safety; antimicrobial residues; food-producing animals; Sokoto-Nigeria.

1.0 INTRODUCTION

Antimicrobial agents are essential for the prevention and treatment of infectious disease in food-producing animals and contribute directly to animal health, welfare, and productivity. Antimicrobial use (AMU) in this sector carries two distinct, though related, public health consequences. The first, more widely studied, is antimicrobial resistance (AMR) selection:

antimicrobial exposure favours resistant microorganisms that can circulate among animals, humans, and environmental compartments, which is why the World Organisation for Animal Health (WOAH) recommends systematic monitoring of AMU by species, agent or class, route, and purpose (World Organisation for Animal Health, 2024). The second, less consistently addressed in veterinary AMU

surveillance, is the food-safety consequence of antimicrobial residues: when antimicrobials are administered without observing the required withdrawal period before slaughter, milking, or egg collection, drug residues can persist in meat, milk, and eggs at concentrations that exceed internationally agreed maximum residue limits (MRLs), set by the Codex Alimentarius Commission following risk assessment by the Joint FAO/WHO Expert Committee on Food Additives (Codex Alimentarius Commission, n.d.). WOAHP identifies protection of human health through food safety, specifically with respect to antimicrobial residues, as a core objective of responsible and prudent antimicrobial use in veterinary medicine, distinct from its resistance-stewardship objective (World Organisation for Animal Health, 2024).

Nigeria has accumulating, if geographically fragmented, empirical evidence that this residue pathway is not merely theoretical. Mustapha *et al.* 2023 detected antimicrobial drug residues, using the Premi® microbial inhibition test, in meat samples from cattle slaughtered in Maiduguri, Borno, and found that administration of antibiotics close to slaughter was significantly more common among marketers, herd owners, and transporters than among butchers and abattoir workers, consistent with a profit-motivated pattern of late-stage antimicrobial use. In poultry and aquaculture products from south-western Nigeria, Onipede *et al.* (2021) quantified tetracycline-class residues, including chlortetracycline at concentrations exceeding EU maximum residue limits, in retail catfish and chicken samples. In a more recent multiclass residue analysis of poultry products consumed in Ogun State, Oyedele *et al.* (2021) detected enrofloxacin, sulfadimethoxine, sulfamerazine, and tylosin at concentrations exceeding permissible MRLs in domestic chicken tissue, all four of which are antimicrobial classes documented in general veterinary use in Nigeria. A broader systematic review of AMR and antimicrobial residues in Nigerian food animals and the environment similarly concluded that residue occurrence is a recurring, if under-monitored, finding across the country (Oloso *et al.*, 2018), and a wider regional review situates Nigeria within a Sub-Saharan African pattern in which veterinary AMU data remain fragmented relative to the scale of the associated food-safety and resistance concern (Odey *et al.*, 2023). The prescribing side of this pathway is similarly documented. Adesokan *et al.* (2015) reported that tetracyclines accounted for 33.6% of antimicrobial use in south-western Nigerian livestock production during 2010–2012, and a national retrospective analysis of veterinary antimicrobial records from 2014 to 2017 confirmed the continued dominance of tetracyclines, alongside penicillin, streptomycin, gentamicin, and sulphadimidine, in Nigerian veterinary practice (Kwange *et al.*, 2023). In poultry specifically, a 12-

state survey of 2,402 farmers found that only 64.2% of respondents administered antimicrobials on veterinary prescription and that 62.3% did not observe recommended withdrawal periods (Njoga *et al.*, 2021), directly linking prescribing behaviour documented at the point of use to the residue risk subsequently measured in retail poultry products by Onipede *et al.* (2021) and Oyedepi *et al.* (2021).

What has been largely absent from this literature is a study that connects species-disaggregated, clinic-level prescribing data directly to this residue-risk evidence base, rather than treating AMU and residue surveillance as separate research traditions. Sokoto State is an important livestock-producing region in north-western Nigeria, where cattle, sheep, goats, and poultry contribute substantially to the regional supply of animal-source foods, yet local clinic-level AMU data remain limited, and a recent survey of livestock farmers in neighbouring Katsina State found that oxytetracycline and penicillin were the antimicrobials most commonly self-administered, alongside generally limited AMR awareness (Salisu *et al.*, 2024), suggesting the same residue-risk dynamics documented elsewhere in Nigeria are plausible in this specific production zone.

The present study therefore analysed retrospective clinical records from a multi-species veterinary clinic in Sokoto, Nigeria, covering 2021–2023, with the explicit aim of interpreting AMU patterns through a food-safety lens. Specifically, the study aimed to: (1) quantify the proportion of food-producing animal clinical cases associated with antimicrobial use; (2) describe AMU patterns by animal species, with attention to which species and agents carry documented residue risk in the Nigerian literature; (3) identify the most frequently documented antimicrobial agents and classes; (4) assess temporal changes in AMU between 2021 and 2023; and (5) characterise antimicrobial entries according to the WHO AWaRe framework, interpreted alongside, rather than as a substitute for, food-safety residue considerations.

2.0. MATERIALS AND METHODS

2.1 Study Design and Setting

A retrospective, record-based study was conducted using clinical data from a multi-species veterinary clinic in Sokoto, Nigeria, covering records generated between January 2021 and December 2023. The analysis was restricted to food-producing animal species represented in the dataset: avian, bovine, caprine, and ovine cases.

2.2 Study Population

Avian, bovine, caprine, and ovine cases were included because these species contribute directly to the production of foods of animal origin consumed in the study area. Canine and feline records were excluded

because they are predominantly companion-animal species. Records without a valid year or species classification were excluded; 14 such records were excluded from the parent dataset, leaving 14,252 food-producing animal cases for analysis.

2.3 Data Extraction and Antimicrobial Classification

Major- and supportive-treatment fields were reviewed for documentation of antimicrobial medicines. Fifteen antimicrobial agents were identified and standardised by generic name, harmonising abbreviated, misspelled, and locally marketed brand names against a reference classification, then grouped into ten pharmacological classes. An antimicrobial-use case was defined as a clinical case in which at least one antimicrobial agent was documented. Antimicrobial-use prevalence therefore represents the proportion of clinical cases with documented antimicrobial use, not a measure of antimicrobial quantity, dose, or treatment duration. Critically for the food-safety interpretation of this study, the clinical records reviewed did not contain a withdrawal-period field, a route-of-administration field distinguishing food animals approaching slaughter from those in ongoing production, or any linkage to post-treatment residue testing; this is a structural limitation of the data source addressed directly in Section 5.

2.4 Measurement of Antimicrobial Frequency

Antimicrobial frequency represents the number of antimicrobial entries documented in the clinical records; a single case could contain more than one entry, so entry totals should not be interpreted as the number of individual animals treated. WOAH recommends quantitative, standardised indicators for more comprehensive monitoring of antimicrobial exposure in food-producing animals (WOAH, 2024), which the present frequency-based approach does not achieve; this is discussed as a limitation.

2.5 WHO AWaRe Classification

Identified antibiotics were additionally classified according to the WHO AWaRe framework (WHO, 2023). Because AWaRe was developed for human antibiotic stewardship and reflects resistance-selection

potential rather than food-safety residue risk, its classification is reported here as a stewardship indicator distinct from, and not a proxy for, the residue-risk interpretation developed in the Discussion from the independent Nigerian residue-testing literature.

2.6 Statistical analysis

Descriptive analyses used frequencies and percentages. Antimicrobial-use prevalence was calculated as the number of clinical cases with documented antimicrobial use divided by the total number of clinical cases, for each species and year. Differences in antimicrobial use between years and species, and in antimicrobial class and AWaRe category distribution, were assessed using Pearson's chi-square test of independence, with Cramér's V describing effect size (small: 0.10–0.19; moderate: 0.20–0.39; large: ≥ 0.40). Statistical significance was assessed at $p < 0.05$. All statistics reported here were computed specifically on the four-species food-producing subset (avian, bovine, caprine, ovine), not on the clinic's broader multi-species caseload, so that reported associations pertain strictly to the food-producing population under study. The species-by-antimicrobial-class contingency table contained 6.8% of cells with expected frequencies below 5; this result was therefore interpreted with reference to effect size alongside p-value. Analyses were conducted in Python 3 using the pandas and SciPy libraries.

3.0 RESULTS

3.1 Characteristics of the study population

A total of 14,252 clinical cases involving food-producing animals were recorded during 2021–2023 (Table 1). Ovine cases constituted the largest proportion (7,014; 49.2%), followed by caprine (4,736; 33.2%), avian (2,214; 15.5%), and bovine cases (288; 2.0%). The overall caseload varied substantially by year (6,938 in 2021, 2,707 in 2022, 4,607 in 2023), with particularly marked fluctuation in ovine (2,737 → 260 → 4,017) and caprine (2,536 → 2,130 → 70) cases; bovine caseload remained comparatively stable (98, 99, 91).

Table 1. Number of food-producing animal clinical cases by species and year, 2021–2023

Species	2021	2022	2023	Total	% of total
Ovine	2737	260	4017	7014	49.2
Caprine	2536	2130	70	4736	33.2
Avian	1567	218	429	2214	15.5
Bovine	98	99	91	288	2.0
Total	6938	2707	4607	14252	100.0

3.2 Overall antimicrobial use

Antimicrobial use was documented in 12,169 of 14,252 cases (85.4%), rising from 84.2% in 2021 to 87.0% in 2022 and 86.2% in 2023 ($\chi^2 = 15.32$, $df = 2$, $p < 0.001$), though the effect size was small (Cramér's $V = 0.033$). This high and rising baseline of antimicrobial exposure

is the starting point for the residue-risk interpretation developed in Section 4: a large majority of food-producing animals passing through this clinic received at least one antimicrobial, with no recorded mechanism for withdrawal-period tracking.

3.3 Species-specific antimicrobial use

Antimicrobial use differed significantly across species ($\chi^2 = 298.05$, $df = 3$, $p < 0.001$; Cramér's $V = 0.145$), highest in ovine (88.0%) and caprine (87.2%) cases and lowest in avian cases (73.7%; Table 2). Temporal patterns also differed by species: bovine and caprine antimicrobial use rose steadily across the three years.

ovine use peaked in 2022, and avian use dipped sharply in 2022 (66.1%) before recovering in 2023 (75.3%). Species-specific year effects were statistically significant for all four species (bovine $p = 0.021$; caprine $p = 0.005$; ovine $p = 0.042$; avian $p = 0.025$).

Table 2. Antimicrobial utilisation rate by species and year, with within-species year-effect statistics

Species	Year 2021, %	Year 2022, %	Year 2023, %	Overall, %	Year-effect χ^2 (df=2)	p
Ovine	88.9	90.8	87.2	88.0	6.36	0.042
Caprine	85.8	88.9	90.0	87.2	10.53	0.005
Bovine	73.5	82.8	89.0	81.6	7.74	0.021
Avian	74.3	66.1	75.3	73.7	7.40	0.025
Overall	84.2	87.0	86.2	85.4	15.32	<0.001

3.4 Antimicrobial agents and their documented food-safety relevance

Across food-producing animals, 14,367 antimicrobial entries were recorded (Table 3). Oxytetracycline was by far the most frequently documented antimicrobial (5,387 entries; 37.5%), followed by the penicillin-streptomycin combination (1,773; 12.3%), sulphadimidine (1,671; 11.6%), tylosin (1,441; 10.0%), and amoxicillin (1,120; 7.8%); these five agents accounted for approximately 79.2% of all entries. Enrofloxacin (781; 5.4%), gentamicin (765;

5.3%), trimethoprim-sulfa (662; 4.6%), and doxycycline (532; 3.7%) followed. Table 3 cross-references each agent against documented Nigerian residue findings: oxytetracycline, tylosin, and enrofloxacin, which together accounted for 52.9% of all antimicrobial entries in this dataset, have each been independently detected above regulatory MRLs in Nigerian beef, poultry, or fish in the published residue-testing literature (Onipede *et al.*, 2021; Oyediji *et al.*, 2021; Mustapha *et al.*, 2023).

Table 3. Antimicrobial agent frequency among food-producing animal cases, 2021–2023, with documented food-safety relevance

Antimicrobial agent	n	Safety relevance	
		%	Food-safety relevance
Oxytetracycline	5387	37.5	Frequently exceeds MRLs in Nigerian beef, poultry, and fish
Penicillin-Streptomycin (combination)	1773	12.3	Beta-lactam and aminoglycoside residue potential
Sulphadimidine	1671	11.6	Long tissue clearance; residue risk in ruminant products
Tylosin	1441	10.0	Detected above MRLs in Nigerian poultry
Amoxicillin	1120	7.8	Beta-lactam residue potential in meat and milk
Enrofloxacin	781	5.4	Detected above MRLs in Nigerian poultry; Watch-category
Gentamicin	765	5.3	Aminoglycoside residue potential
Trimethoprim-Sulfa	662	4.6	Sulfonamide component residue potential
Doxycycline	532	3.7	Tetracycline-class residue potential
Metronidazole	122	0.8	Prohibited in food animals in several jurisdictions
Penicillin	35	0.2	Beta-lactam residue potential
Chloramphenicol	34	0.2	Banned in food animals in most jurisdictions; zero-tolerance residue
Ceftriaxone	34	0.2	Watch-category; reserved-use concern
Streptomycin	9	0.1	Aminoglycoside residue potential
Ciprofloxacin	1	<0.1	Watch-category fluoroquinolone
Total	14367	100.0	

3.5 Antimicrobial classes

Tetracyclines were the predominant class (5,919 entries; 41.2%; Table 4), followed by the penicillin-aminoglycoside combination (12.3%), sulfonamides (11.6%), and macrolides (10.0%). Class distribution differed significantly by year ($\chi^2 = 542.53$, $df = 20$, $p < 0.001$; Cramér's $V = 0.137$) and by species ($\chi^2 = 1894.72$, $df = 30$, $p < 0.001$; Cramér's $V = 0.210$, a moderate effect). This class-level concentration is

directly relevant to food safety, since residue risk is a property of the specific compound and species combination rather than of prescribing volume alone, and the three leading classes here; tetracyclines, the penicillin-aminoglycoside combination, and sulfonamides, correspond closely to the classes flagged in the Nigerian residue-testing literature cited in Section 4.

Table 4. Antimicrobial class distribution among food-producing animal cases, 2021–2023

Antimicrobial class	n	%
Tetracyclines	5919	41.2
Penicillin + Aminoglycoside combination	1773	12.3
Sulfonamides	1671	11.6
Macrolides	1441	10.0
Beta-lactams (Penicillins)	1155	8.0
Fluoroquinolones	782	5.4
Aminoglycosides	774	5.4
Sulfonamide + Trimethoprim combination	662	4.6
Nitroimidazoles	122	0.8
Amphenicols	34	0.2
3rd-generation Cephalosporins	34	0.2

3.6 AWaRe classification and species-specific residue risk

Exploratory AWARe classification indicated 12,076 entries (84.1%) as Access and 2,291 (15.9%) as Watch (Table 5); no Reserve-category agents were recorded. The Watch-category share was highest in avian cases (22.3%), a species in which macrolides (tylosin) and

fluoroquinolones (enrofloxacin), both independently documented above MRLs in Nigerian poultry-residue studies (Oyedemi *et al.*, 2021), were disproportionately represented relative to other species (Table 4, Section 3.5). AWARe category differed significantly by year ($\chi^2 = 22.53$, $df = 2$, $p < 0.001$) and species ($\chi^2 = 86.35$, $df = 3$, $p < 0.001$).

Table 5. WHO AWaRe classification of antimicrobial entries by food-producing species, 2021–2023

Species	Access, n (%)	Watch, n (%)	Reserve, n (%)
Ovine	5950 (85.6)	1003 (14.4)	0 (0.0)
Caprine	4072 (85.0)	720 (15.0)	0 (0.0)
Bovine	227 (84.1)	43 (15.9)	0 (0.0)
Avian	1827 (77.7)	525 (22.3)	0 (0.0)
Overall	12076 (84.1)	2291 (15.9)	0 (0.0)

As in Section 3.2, this Access-dominant profile should not be read as evidence of food-safety-adequate prescribing: AWaRe reflects human resistance-selection concern, not residue risk, and a high Access-category share is entirely compatible with substantial residue exposure if the underlying volume of Access-category antibiotics, overwhelmingly tetracyclines here, is itself very high and administered without documented withdrawal-period guidance.

4.0 DISCUSSION

4.1 A documented, not merely theoretical, residue-risk pathway

The central finding of this study, that oxytetracycline alone accounted for more than one-third of all antimicrobial entries among food-producing animals in this Sokoto clinic, gains its practical significance from its convergence with independent Nigerian residue-surveillance evidence. Onipede *et al.* (2021) subsequently quantified tetracycline-class residues, including concentrations of chlortetracycline exceeding EU maximum residue limits, in retail catfish and chicken from south-western Nigeria. Because the present dataset shows tetracyclines, chiefly oxytetracycline, as the dominant class prescribed to bovine and ovine cases specifically, the prescribing pattern documented here is directly consistent with the residue findings reported at Nigerian abattoirs and retail markets, rather than a hypothetical extrapolation from prescribing volume alone.

The picture is similarly direct for poultry. Oyedeji *et al.* (2021) detected enrofloxacin, sulfadimethoxine, sulfamerazine, and tylosin above permissible MRLs in domestic chicken tissue consumed in Ogun State, all four representing antimicrobial classes recorded in this dataset's avian caseload; tylosin (macrolides) and enrofloxacin (fluoroquinolones) together accounted for a disproportionate share of avian antimicrobial entries and of the elevated avian Watch-category share reported in Section 3.6. Njoga *et al.* (2021) offers a plausible behavioural explanation for this pattern: in a 12-state survey of 2,402 Nigerian poultry farmers, only 64.2% administered antimicrobials on veterinary prescription and 62.3% did not observe recommended withdrawal periods, a farm-level practice gap that would be expected to translate directly into the retail-level residues subsequently measured by Oyedeji *et al.* (2021) and Onipede *et al.* (2021).

4.2 Species-specific food-safety considerations

The species-level variation documented in this study (Section 3.3) carries distinct food-safety implications depending on the food product at stake. Ovine and caprine cases, which showed the highest antimicrobial-use prevalence (88.0% and 87.2%, respectively) and the heaviest tetracycline burden, correspond to meat and, for caprine and ovine dairy animals, milk products consumed fresh and often without the extended cold-chain processing that can allow some residue degradation; the near-total reliance on tetracyclines and

sulphadimidine in these species (Table 4) concentrates residue risk in a narrow set of well-characterised, and independently residue-confirmed, compounds. Avian cases, despite the lowest overall antimicrobial-use prevalence, carry a disproportionate food-safety signal because poultry meat and eggs are consumed with comparatively short farm-to-table intervals, leaving little time for residue clearance even when withdrawal periods are nominally observed, and because the specific classes elevated in avian prescribing here (macrolides, fluoroquinolones) are precisely those flagged in Nigerian poultry-residue testing (Oyedemi *et al.*, 2021). Bovine cases, while numerically the smallest group in this dataset (288 cases), warrant particular attention given the documented 74.8% (37/50) antibiotic residues in beef samples in Maiduguri (Mustapha *et al.*, 2023) and the comparatively low absolute case numbers meaning a small number of poorly managed treatment episodes could disproportionately affect the regional beef supply.

4.3 Regulatory and surveillance gaps

Nigeria's food-safety regulatory architecture for veterinary antimicrobial residues exists in principle, anchored in the Codex Alimentarius Commission's internationally negotiated maximum residue limits (Codex Alimentarius Commission, n.d.) and in WOA's standards for responsible and prudent antimicrobial use, which explicitly identify residue-related food safety as a distinct objective from resistance stewardship (World Organisation for Animal Health, 2024). In practice, however, none of the clinical records reviewed in this study documented withdrawal-period counselling, treatment-to-slaughter interval, or post-treatment residue testing, a gap consistent with the wider African and Nigerian evidence: One of the major challenge is inadequate funding, which limits the development of infrastructure, access to essential resources, staff training, and the effective implementation of monitoring activities. In addition, inconsistent political commitment and weak governance often result in fragmented policies, poor enforcement of regulations, and limited long-term investment in antimicrobial resistance (AMR) control. The widespread availability of substandard and poor-quality antibiotics also remains a serious concern, as these medicines can reduce treatment effectiveness and make efforts to control AMR more difficult (Ndaki *et al.*, 2025). Njoga *et al.* (2021) documented majority non-compliance with withdrawal periods at the farm level nationally. This study's findings extend that evidence to the veterinary clinical encounter itself, the point at which withdrawal-period guidance would normally be delivered, and finds no structural mechanism in the records reviewed for ensuring that guidance occurs or is tracked.

4.4 Reframing antimicrobial stewardship through a food-safety lens

The high proportion of Access-category antimicrobial entries (84.1%) nominally exceeds the WHO's 60% Access-category benchmark (World Health Organization, 2023), which, read through a resistance-stewardship lens alone, could be presented as a favourable finding. Read through a food-safety lens, however, the same finding is more concerning: it indicates that the overwhelming majority of antimicrobial exposure in this food-producing animal population is concentrated in a small number of high-volume, long-tissue-clearance compounds, principally oxytetracycline and sulphadimidine, that are precisely the classes most frequently implicated in Nigerian residue-exceedance findings (Onipede *et al.*, 2021; Ghimpeanu *et al.*, 2022; Mesfin *et al.*, 2024). This is a direct illustration of why AWaRe classification, though a useful resistance-stewardship indicator, cannot substitute for dedicated residue surveillance in food-producing animal antimicrobial policy: a prescribing profile can be simultaneously Access-dominant and high-residue-risk. The wider regional and global context reinforces the stakes of this distinction: bacterial AMR was associated with 4.95 million deaths globally in 2019, with the highest regional burden in Sub-Saharan Africa (Antimicrobial Resistance Collaborators, 2022), documented multidrug-resistant non-typhoidal *Salmonella* has been isolated from Nigerian cattle, abattoir environments, and humans in the same production chain (Aworh *et al.*, 2024), and global antimicrobial consumption in food animals is projected to keep rising through 2030, with the steepest increases expected in low- and middle-income countries undergoing production intensification (Tiseo *et al.*, 2020). In 2020, global antimicrobial use was estimated at 99,502 tonnes. If current trends continue, usage is expected to rise by 8.0%, reaching approximately 107,472 tonnes by 2030. Asia accounted for most antimicrobial-use hotspots, representing 67%, whereas Africa accounted for less than 1%. The projected global use for 2030 is higher than earlier estimates based on 2017 data, considerably because antimicrobial-use figures were modified upward for Asia and Oceania by about 6,000 tonnes and for the Americas by roughly 4,000 tonnes (Mulchandani *et al.*, 2023). These figures describe the resistance-selection burden rather than the residue-risk burden that is this study's primary concern, but they establish that the prescribing volumes documented here are part of a rising regional trend, which makes the absence of withdrawal-period tracking identified in Section 4.3 an increasingly, not merely currently, pressing food-safety gap.

4.5 Policy relevance

These findings map directly onto the food-safety objectives of Nigeria's One Health AMR National Action Plan 2.0, which addresses both antimicrobial



stewardship and residue-relevant food-safety surveillance in the animal-health sector (Federal Ministries of Agriculture and Food Security, Environment, and Health and Social Welfare, 2024), building on the surveillance mandate of Nigeria's first National Action Plan. Clinic-level data of the kind reported here could feasibly be linked to abattoir- and market-level residue testing of the type conducted by Onipede *et al.* (2021), and Oyediji *et al.* (2021), creating a farm-to-fork surveillance chain that currently does not exist in a connected form for this production zone. WOA's standards for monitoring antimicrobial quantities and usage patterns in food-producing animals (World Organisation for Animal Health, 2024) provide an internationally recognised template for how such linkage could be structured.

5. LIMITATIONS

Several limitations qualify these findings, particularly for their food-safety interpretation. First, and most directly relevant to the residue-risk argument developed in Section 4, the clinical records reviewed contained no withdrawal-period field, no treatment-to-slaughter interval, and no linkage to residue testing; the food-safety implications drawn here are therefore an evidence-based inference from the documented prescribing pattern and its convergence with independent Nigerian residue-testing studies, not a direct residue measurement from this clinic's own caseload.

Secondly, prescribing data reflect what clinicians recorded, not confirmed administration, dose, or duration, so true antimicrobial exposure in standard units could not be estimated, consistent with WOA's distinction between prescribing-frequency data and quantitative exposure indicators (World Organisation for Animal Health, 2024).

Third, case volume fluctuated markedly within some species across years, most plausibly reflecting variation in clinical-register completeness rather than true changes in regional caseload, which limits causal interpretation of the year-on-year trends reported.

Fourth, brand-to-ingredient mappings for locally marketed combination products could not be independently verified against this clinic's pharmacy records.

Fifth, approximately 1.1% of drug mentions in the parent dataset could not be confidently classified and were excluded.

Sixth, the AWARe framework was developed for human medicine, and its veterinary thresholds are not formally validated (World Health Organization, 2023); it is reported here as a stewardship indicator distinct from the food-safety residue-risk argument, which instead draws on dedicated Nigerian residue-testing literature.

Finally, this is single-facility data from one veterinary clinic in Sokoto State and may not generalise to other clinics, production systems, or regions of Nigeria.

6. CONCLUSION

Antimicrobial use among food-producing animal cases at this Sokoto veterinary clinic was frequent (85.4% of cases) and heavily concentrated in tetracyclines, chiefly oxytetracycline, throughout 2021–2023, with statistically significant variation by species and year. This prescribing pattern converges closely with the specific antimicrobial classes, tetracyclines, macrolides, and fluoroquinolones, independently confirmed to exceed regulatory maximum residue limits in Nigerian beef, poultry, and fish by dedicated residue-testing studies conducted elsewhere in the country.

Although, the clinical records reviewed contained no withdrawal-period documentation or residue-testing linkage, this convergence cannot be resolved into a direct measurement of residue occurrence in this clinic's own caseload. Still, it is sufficient to establish food safety, not only antimicrobial resistance, as a proximate and evidence-based concern arising from the prescribing pattern documented here. Linking clinic-level antimicrobial-use surveillance of the kind reported in this study to abattoir- and market-level residue testing, and introducing structured withdrawal-period documentation at the point of veterinary prescribing, should be treated as a public health priority for food-producing animal practice in Sokoto State.

REFERENCES

- Antimicrobial Resistance Collaborators. (2022). Global burden of bacterial antimicrobial resistance in 2019: A systematic analysis. *The Lancet*, 399(10325), 629–655. [https://doi.org/10.1016/S0140-6736\(21\)02724-0](https://doi.org/10.1016/S0140-6736(21)02724-0)
- Aworh, M. K., Nilsson, P., Egyir, B., Owusu, F. A., & Hendriksen, R. S. (2024). Rare serovars of non-typhoidal *Salmonella enterica* isolated from humans, beef cattle and abattoir environments in Nigeria. *PLOS ONE*, 19(1), Article e0296971. <https://doi.org/10.1371/journal.pone.0296971>
- Codex Alimentarius Commission. (n.d.). Maximum residue limits (MRLs) and risk management recommendations (RMRs) for residues of veterinary drugs in foods (CXM 2). Food and Agriculture Organization / World Health Organization. <https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/vetdrugs/veterinary-drugs/en/>
- Federal Government of Nigeria. (2017). National action plan for antimicrobial resistance (2017–2022). Federal Ministry of Agriculture and Rural Development / Federal Ministry of Health.
- Federal Ministries of Agriculture and Food Security, Environment, and Health and Social Welfare. (2024). One Health antimicrobial resistance national action

IJSGS FUGUSAU VOL. 12(3)

WEBSITE: <https://fugus-ijsgs.com.ng>

- plan 2.0 (2024–2028). Nigeria Centre for Disease Control.
- Ghimpețeanu, O. M., Pogurschi, E. N., Popa, D. C., Dragomir, N., Drăgotoiu, T., Mihai, O. D., & Petcu, C. D. (2022). Antibiotic use in livestock and residues in food—A public health threat: A review. *Foods*, 11(10), Article 1430. <https://doi.org/10.3390/foods11101430>
- Kwange, D., Ndahi, M. D., Alabi, O., Usman, B. A., Umanah, P., Andersen, J. K., & Kwaghe, A. V. (2023). A retrospective study on veterinary antimicrobial use in Nigeria, 2014 to 2017. *Pan African Medical Journal*, 45, Article 104. <https://doi.org/10.11604/pamj.2023.45.104.32046>
- Mesfin, Y. M., Mitiku, B. A., & Tamrat Admasu, H. (2024). Veterinary drug residues in food products of animal origin and their public health consequences: A review. *Veterinary Medicine and Science*, 10(6), Article e70049. <https://doi.org/10.1002/vms3.70049>
- Mulchandani R, Wang Y, Gilbert M, Van Boeckel TP (2023) Global trends in antimicrobial use in food-producing animals: 2020 to 2030. *PLOS Glob Public Health* 3(2): e0001305. <https://doi.org/10.1371/journal.pgph.0001305>
- Mustapha, A., Isa, T., Musa, S. I., Abdullahi, M. G., Mahmoud, F. Z., Sani, M. I., Micheal, M. O., Mohammed, J. M., Muhammad, F. L., Balumi, H., Ahmed, U., Jacob, L., Bukar, H., Audu, F. G. and Musa, M. I. (2023). Antibiotic Residues in fresh Chicken, Fish and Beef Meat samples in Maiduguri, Nigeria. *Sahel J. Vet. Sci.* 20(3), Pp 53-58
- Ndaki, P. M., Mwanga, J. R., Mushi, M. F., Konje, E. T., Mwita, S. M., Mshana, S. E. (2025). Drivers of inappropriate use of antibiotics among community members in low- and middle-income countries: a systematic review of qualitative studies. *BMC Public Health* 25, 705. doi: 10.1186/s12889-025-21553-6
- Njoga, E. O., Ogugua, A. J., Nwankwo, I. O., Awoyomi, O. J., Okoli, C. E., Buba, D. M., Oyeleye, F. A., Ajibo, F. E., Azor, N., & Ogunniran, T. M. (2021). Antimicrobial drug usage pattern in poultry farms in Nigeria: Implications for food safety, public health and poultry disease management. *Veterinaria Italiana*, 57(1), 5–12. <https://doi.org/10.12834/VetIt.2117.11956.1>
- Odey, T. O. J., Tanimowo, W. O., Afolabi, K. O., Jahid, I. K., & Reuben, R. C. (2023). Antimicrobial use and resistance in food animal production: Food safety and associated concerns in Sub-Saharan Africa. *International Microbiology. Advance online publication*. <https://doi.org/10.1007/s10123-023-00462-x>
- Onipede, O. J., Nwankwo, B., Adewuyi, G. O., & Nwachukwu, C. U. (2021). Levels of antibiotics residues in chicken and catfish sold in some parts of Lagos State and Ota Local Government, Ogun State, south-western Nigeria. *Scientific African*, 12, Article e00768. <https://doi.org/10.1016/j.sciaf.2021.e00768>
- Oyedede, A. O., Msagati, T. A. M., Williams, A. B., & Benson, N. U. (2021). Detection and quantification of multiclass antibiotic residues in poultry products using solid-phase extraction and high-performance liquid chromatography with diode array detection. *Heliyon*, 7(12), Article e08469. <https://doi.org/10.1016/j.heliyon.2021.e08469>
- Salisu, U., Ladan, S., Abdullahi, S. M., Cook, P. A., Haruna, Z. S., Koguna, M. M., & Umar, S. (2024). Awareness of antimicrobial usage and antimicrobial resistance (AMR) among livestock farmers in Katsina State, Nigeria. *Direct Research Journal of Veterinary Medicine and Animal Science*, 9(1), 52–64.
- Tiseo, K., Huber, L., Gilbert, M., Robinson, T. P., & Van Boeckel, T. P. (2020). Global trends in antimicrobial use in food animals from 2017 to 2030. *Antibiotics*, 9(12), Article 918. <https://doi.org/10.3390/antibiotics9120918>
- World Health Organization. (2023). AWARe classification of antibiotics for evaluation and monitoring of use, 2023 (WHO/MHP/HPS/EML/2023.04).
- World Organisation for Animal Health. (2024). Terrestrial animal health code (32nd ed.). <https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/>